02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Paul R Bierman

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☐

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Lee B Corbett

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☐

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

Not for distribution

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 15-1 **NSF 15-516**	**FOR NSF USE ONLY** **NSF PROPOSAL NUMBER**
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) **EAR - INSTRUMENTATION & FACILITIES**	

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				066811191	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY?
030179440	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE **University of Vermont & State Agricultural College**	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE **University of Vermont & State Agricultural College 85 SO. PROSPECT ST. BURLINGTON, VT. 054050160**
AWARDEE ORGANIZATION CODE (IF KNOWN) **0036962000**	
NAME OF PRIMARY PLACE OF PERF **University of Vermont & State Agricultural College**	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE **University of Vermont & State Agricultural College 180 Colchester Avenue Burlington ,VT ,054050160 ,US.**

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions) ☐ SMALL BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Facility Support: Community sample preparation facility for broadening participation, research, and hands-on research training in cosmogenic nuclide studies**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **0**	**36** months	**07/01/16**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ BEGINNING INVESTIGATOR (GPG I.G.2)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
- ☐ HISTORIC PLACES (GPG II.C.2.j)
- ☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________ PHS Animal Welfare Assurance Number ________
- ☒ FUNDING MECHANISM **Facility/Center**
- ☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ________ Exemption Subsection ________ or IRB App. Date ________
- ☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
- ☒ COLLABORATIVE STATUS **Not a collaborative proposal**

PI/PD DEPARTMENT **Department of Geology**	PI/PD POSTAL ADDRESS **Delehanty Hall 180 Colchester Ave Burlington, VT 05405 United States**
PI/PD FAX NUMBER **802-656-0045**	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Paul R Bierman**	**PhD**	**1993**	**802-656-4411**	**pbierman@uvm.edu**
CO-PI/PD **Lee B Corbett**	**MS**	**2011**	**802-380-2344**	**Ashley.Corbett@uvm.edu**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide,Part I: the Grant Proposal Guide (GPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of AAG Chapter IV.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations.
By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER

Project Summary

Facility Support: Community sample preparation facility for broadening participation, research, and hands-on research training in cosmogenic nuclide studies

We seek NSF support to staff a national facility for consistent, reliable, high-quality preparation of samples for cosmogenic nuclide analysis (^{10}Be and ^{26}Al) using a hands-on model that integrates research and research training for graduate students, undergraduate students, researchers, and faculty. Over the past several decades, the use of these nuclides in earth science has increased dramatically. However, sample preparation remains tedious, difficult, and hazardous, requiring strong mineral acids and correspondingly complicated and expensive clean laboratory facilities that are not readily available. Thus, many STEM students, researchers, and faculty do not have access to these increasingly important nuclides as tools for approaching research questions in fields such as surface earth processes, climate change, hydrology, land management, and sediment transport.

Here, we present a plan for a three-year, proof-of-concept that makes available a long-standing, state-of-the-art, high-throughput, cosmogenic nuclide clean laboratory sample preparation facility to the broader geoscience community. We seek salary for a doctoral-level lab manager whose primary function will be to train and support visiting students and faculty as they process samples collected as part of established or beginning research projects. Such an approach is cost-effective because it relies on existing physical and intellectual infrastructure and builds on successful research and research training efforts of the PI and lab manager. We propose proactive, collaborative outreach activities to engage students and faculty at both undergraduate institutions and institutions serving communities underrepresented in the geosciences. The strengths and weaknesses of our approach will be informed by independent formative assessment during the program and by a summative assessment at the conclusion of three years.

Intellectual Merit – Ours is a new approach aimed at broadening participation in the rapidly expanding field of cosmogenic isotope geoscience by opening a long-recognized geochemistry laboratory to the community. Building upon established sample-processing and training protocols, we will facilitate research by increasing access to ^{10}Be and ^{26}Al sample preparation. Because of limited laboratory space, the cosmogenic nuclide community has remained relatively small. Providing a national sample preparation facility will catalyze the inclusion of new and different scientists in the cosmogenic community increasing not only the number but diversity of projects involving these isotopes – a catalyst for transformative research.

Broader Impacts – Supporting a community facility for sample processing and research training will have numerous different broader impacts. 1. It directly addresses a current bottleneck in cosmogenic nuclide studies: the extraction of beryllium and aluminum from rock, soil, and sediment that precedes isotopic measurement. 2. It democratizes the use of these nuclides by providing access to a state of the art sample processing facility at an institution dedicated to research and research training. 3. Our outreach program goes directly to faculty and students at institutions serving communities under-represented in the geosciences and our seed grant program brings faculty/student teams to the laboratory for meaningful collaboration and hands-on training. 4. Facility support provides, dedicated hands-on research training in isotopic clean lab methods for students, researchers, and faculty in a variety of geoscience disciplines.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Project Description

1. Overview

We propose a new model for providing national access to a community geochronology facility dedicated to the preparation of cosmogenic nuclide samples (^{10}Be and ^{26}Al) used for exposure dating, erosion rate determination, sediment tracing, and hydrologic studies. Our approach cost-effectively provides a state-of-the-art venue for efficient hands-on research and research training to students, faculty, and post-doctoral researchers. We seek to broaden participation in isotope geoscience while addressing a current bottleneck – the need for accessible clean room facilities for the time-consuming, complicated processing of samples prior to isotopic analysis. NSF support of such a facility will democratize access to this increasingly important and cutting-edge technique in a variety of different geoscience fields.

Specifically, we request salary support for a Laboratory Manager so that we can open an existing, purpose-built facility with significant excess sample capacity to the broader geoscience community. Our plan involves close mentoring of visiting students, faculty, and post-doctoral researchers who will process their own samples under the guidance of an experienced cosmogenic geochemist. Consistent with the PI's and CoPI's experience and goals, we have developed a proactive outreach program to increase participation in isotope geoscience by a larger and more diverse group of students, faculty, and researchers. Because we consider this a proof-of-concept proposal, we have included both formative and summative evaluation of our approach so that we can respond to community needs during the project and judge objectively whether it is worth continuing into the future. This proposal responds directly to a call for such centralized research and research training facilities in the recent NSF-supported report, *It's About Time: Opportunities & Challenges for U.S. Geochronology* (Harrison et al., 2015).

2. Why fund a community sample preparation facility for cosmogenic nuclides?

Cosmogenic radionuclides, including ^{10}Be and ^{26}Al, are widely used to address a variety of questions in geoscience, providing insight about glacial chronology (Fabel and Harbor, 1999; Balco, 2011), subglacial preservation of ancient surfaces (Bierman et al., 1999), solar forcing (Bard et al., 2000), erosion rates (von Blanckenburg, 2005; Portenga and Bierman, 2011), sediment budgets (Nichols et al., 2005), and tectonic processes (Mitchell et al., 2001; Balco et al., 2010; Behr et al. 2011). New applications of cosmogenic nuclides proposed in recent years, such as burial isochron dating (Balco and Rovey, 2008) and the renaissance of meteoric ^{10}Be (Graly et al., 2010; Graly et al., 2011; Willenbring and von Blanckenburg, 2010), ensure that the field will continue to grow (Bacon et al., 2012; Bierman et al., 2014; von Blanckenburg et al., 2012; Wittman et al., 2012; Erlanger et al., 2012).

Cosmogenic sample analysis is a multi-stage process (Bierman et al., 2002; Gosse and Phillips, 2001; Granger et al., 2013) that begins with field sampling and ends with Accelerator Mass Spectrometry (AMS). Between fieldwork and AMS is sample processing, the most time consuming, tedious, and hazardous step. During sample processing, different earth materials are separated, then dissolved in strong acids before the elements of interest are extracted and purified (Hunt et al., 2008). For example, preparation of soil, sediment, or rock samples for measurement of ^{10}Be and ^{26}Al in quartz (by far the most common cosmogenic isotopic system) requires crushing, sieving, magnetic separation, repeated acid etching, HF dissolution, column chemistry, then oxidation and physical packing into AMS cathodes – a process that can take 2+ months for a few dozen samples and requires specialized, costly facilities and equipment.

By our count, there are 32 laboratories currently preparing samples for in situ cosmogenic analysis in the United States (Bierman et al., 2015); only a fraction of these labs routinely process samples for meteoric ^{10}Be. Most existing facilities are run by faculty and have no technical support. Thus, they have no easy or consistent means to accept, train, and mentor visitors - a time consuming and potentially risky endeavor given the large volumes of strong acids used in sample processing. A few labs, such as PRIME, the NSF-supported AMS facility, offer fee-for-service sample preparation and the possibility for visitors to process their own samples; however, most laboratories service only the director, associated graduate students, and post-doctoral researchers. There are no US commercial sample processing facilities.

Cosmogenic sample preparation laboratories vary greatly in size and sample throughput. Most process a few dozen samples a year without technical support staff, although several process hundreds of samples each year. Laboratory infrastructure also varies tremendously. The most effective laboratories occupy dedicated cleanrooms and produce consistently pure samples which have high beam currents on the AMS and very low blanks; such samples run consistently well during isotopic analysis and produce the most reliable and precise data (Zimmerman et al., 2014). Because almost all cosmogenic radiochemistry is done in solution, having analytical capabilities, such as an Inductively Coupled Plasma (ICP) or Atomic Absorption Spectroscopy (AA), on site improves troubleshooting, quality control, and sample outcomes; yet, most cosmogenic laboratories do not have easy, cost-effective access to such instruments.

Cosmogenic nuclide sample processing facilities are expensive to construct and difficult to maintain. Producing consistent, high-yield, isobar-free, low blank samples requires experience, robust methods, large amounts of teflon labware, filtered air, and clean water. Large volumes of dilute waste acid are best and most efficiently handled by dedicated acid neutralization systems – another rarity. The result is that most geoscientists in the United States have no access to cosmogenic sample processing facilities; those that have access tend to be located at large research institutions with significant budgets for infrastructure. No sample processing facilities are located at colleges and universities predominately serving groups under-represented in the geosciences, such as Tribal Colleges (TCs) and Historically Black Colleges and Universities (HBCUs). Nor are many undergraduates able to access such facilities routinely-only three small laboratories are located at Primarily Undergraduate Institutions (PUI).

The lack of easily accessible facilities has several implications: a burgeoning technique in the geosciences is utilized by relatively few practitioners, there is little exposure to the technique for undergraduates who make up the next generation of geoscientists, those without laboratory facilities often pay to have samples processed by others but do not understand or appreciate the complexities and uncertainties underlying the resulting data, and the population of cosmogenic geochemists is overwhelmingly white and male. Of the 32 sample processing facilities in the United States, only 6 are run by women; none are run by ALANA scientists. Most importantly and hardest to quantify, the lack of broad geoscience community involvement in cosmogenic geoscience almost certainly means that transformative ideas, which are likely to come from those thinking outside traditional applications of these nuclides, do not often see the light of day.

NSF support of a community sample preparation facility for cosmogenic nuclides will provide a high quality, easily accessible, clean laboratory environment where students, faculty, and post-doctoral researchers can process samples with instruction and mentoring from an experienced geochemist. The result will be a broadening in participation, an increase in the number and quality of cosmogenic samples reaching AMS facilities, and a potentially transformative diversification of the geoscience questions addressed with cosmogenic nuclides.

3. Project Personnel and Management

We have assembled a strong team including a senior cosmogenic scientist (Bierman), a junior scientist with extensive cosmogenic and outreach training (Corbett), an assessment specialist with strong ties to the Native American Community and TCs (Semken), and the former Dean of Science at Morgan State University (Whittaker) who will advise us on the most effective means of cultivating long-lasting and effective relationships with institutions, such as HBCUs, serving populations under-represented in the geosciences. Bierman will manage the project. Corbett will manage the laboratory. Semken will perform assessment and assist with TC engagement while Whittaker will advise us on best practices for engagement with those under-represented in the geosciences.

Bierman was among the first cohort of cosmogenic geoscientists when he began work with these isotopes in 1990. He has broad experience using ^{10}Be and ^{26}Al as erosion rate monitors, dating tools, and as a means to trace sediment from source to sink. Bierman has directed the cosmogenic laboratory at the University of Vermont since 1993 and in the last 22 years has been primary advisor to 36 graduate students including 6 doctoral and 30 Masters students, 17 of whom were woman. He has advised three post-doctoral associates. Bierman, his students, and collaborators have effectively disseminated a diverse body of scholarly work, much of it using isotope geoscience, in over 80 peer reviewed articles. Bierman is dedicated to geoscience education and outreach as demonstrated by his authorship of a new style of textbook (Bierman and Montgomery, 2014) supported by NSF, several geoscience education articles, his direction of the NSF supported Landscape Change Program (http://uvm.edu/landscape), and his NSF-DTS award in 2005 recognizing his integration of research and teaching.

Corbett has seven years of experience processing cosmogenic samples, has broad geoscience field expertise, and has trained several of the visitors listed in Table 1. A graduate of Middlebury College, she is familiar with the culture of PUIs. Corbett was integral to the development of the Vermont cosmogenic facility in 2008-2009 and has worked closely with Bierman on methodological optimization. She has significant experience teaching several courses at both the University of Vermont and Middlebury College. Corbett contributed to geoscience education through conference presentations (Corbett et al., 2011a; Corbett and West, 2012) and the peer-reviewed literature (Reusser et al., 2012). She has diverse experience with cosmogenic nuclides, making her a useful collaborator on a wide range of potential projects including: glacial chronology (Corbett et al., 2015; Corbett et al., 2011b; Young et al., 2013, Bierman et al., *in press;* Davis et al., 2015), subglacial preservation of ancient surfaces (Corbett et al., *in review-a;* Corbett et al., 2013a), sediment recycling (Corbett et al., *in review-b*), and erosion rate studies (Portenga et al., 2015). She is now pursuing novel applications of ^{10}Be and ^{26}Al to understanding long-term (millions of years) glacial history and process by analyzing sediments at the bottom of the GISP2 ice core (Bierman et al., 2014) and in marine cores off of both Greenland and Antarctica, all of which required innovative approaches in the laboratory to account for small sample masses and low ^{10}Be/^{9}Be ratios.

Semken…. Steve, can you please help with a short bio paragraph.

Whittaker…. Joe, can you please help with a short bio paragraph.

4. Impact on existing facilities?

We anticipate only positive impacts on existing facilities. Since we will not do "fee for service" sample processing, there should be no impact on the demand for sampling processing services offered currently by PRIME lab. Existing single investigator laboratories will continue to function as they do today, processing samples for students and faculty at their own institutions and for collaborators. In the past, we have hosted nearly a dozen faculty who were either starting up their own laboratories or troubleshooting issues with sample processing. We anticipate that these visits will continue and expand under NSF facility support. Because the capacity of our existing facility will be much more effectively used, double the number of samples will be processed each year, thereby increasing data production, but without the costs of developing a new physical facility. This will foster the continued rapid growth that cosmogenic nuclide research has experienced over recent decades (Balco, 2011). Adding sample preparation capacity will increase the number of samples that need to be analyzed by AMS, putting more demand on PRIME and Livermore. If these facilities cannot handle the load, then the many new AMS facilities being installed abroad (Bierman et al., 2015) should be able to assist.

5. Existing Facility: The University of Vermont Cosmogenic Nuclide Laboratory

The University of Vermont Cosmogenic Nuclide Laboratory (CNL) is a purpose-build, state-of-the-art facility that has been in operation since 2009; it is the latest iteration of a laboratory that began in 1993 (http://uvm.edu/cosmolab). Over the past 6 years, 21 graduate students, undergraduate students, and post-doctoral researchers, working with director Bierman, have processed >2000 samples for in situ $^{10}Be/^{26}Al$ and >1600 samples for meteoric ^{10}Be in the laboratory. Ours is an ideal laboratory for hosting visiting students because of its emphasis on safety, standardized methods, and our demonstrated ability, reflected in over 60 peer-reviewed publications, to successfully extract beryllium and aluminum from a wide variety of samples with high yield and low backgrounds. The laboratory maintains an extensive web presence with specific pages providing all of our methods, facilities, construction plans, and publications (http://uvm.edu/cosmolab).

5.1. Facilities

The University of Vermont Department of Geology houses three separate facilities used directly in cosmogenic nuclide sample processing. For details and photographs, see the facilities description at end of this proposal. 1) We have a rock room (320 ft^2) that contains all new equipment for rock crushing, grinding, and sieving, including a CARPCO roll separator for rapid, high-volume magnetic separations (purchased by NSF VT EPSCOR) and a SPEX shatter-box used for powdering samples for meteoric ^{10}Be analysis. 2) We use a mineral separation laboratory (330 ft^2) dedicated to cosmogenic nuclide work, specifically the preparation of pure quartz. The mineral separation laboratory is optimized for the isolation of large volumes of purified quartz, contains ten large ultrasounds for HCl and HF/HNO_3 etching, and two hoods, one used for acid handling and the other for density separation. We also have the capability to do phosphoric acid purification of quartz (Mifsud et al., 2013). 3) We operate a class 1000 cleanroom (880 ft^2) for isotopic extraction. The clean room contains four subrooms: a vestibule for cleanliness, safety, deliveries, and material handling; a room for the isolation of meteoric beryllium and testing of quartz purity; the *in situ* laboratory containing two separate processing streams for high- and low-$^{10}Be/^{9}Be$ samples; and a naturally lit, carpeted area for faculty and students to meet, work, and eat that is hazardous materials-free. Both the meteoric and *in situ* clean laboratories contain infrastructure for quartz digestion, acid treatments, column chromatography, hydroxide precipitation, and a glove box used for packing AMS cathodes for analysis. In total, we have five fully exhausting laminar flow hoods and all air is ULPA filtered to reduce boron contamination in samples (^{10}B is an isobar that can interfere with the measurement of ^{10}Be). Because our renovated building is equipped with an acid neutralization system serving the drains from all laboratories, we can easily, efficiently, safely, and legally dispose of all dilute waste using in-hood sinks. Members of the CNL make frequent use a JY Horiba, Optima 2 ICP-OES (NSF-EAR-0132169, Bierman) that was updated in 2015 with all new data acquisition capabilities (supplement to NSF-ARC-1023191, Bierman). The ICP is located immediately adjacent to the cosmogenic facilities.

5.2. Methodological Approach and Optimization

At the University of Vermont, we have adapted and refined existing methods both for extracting ^{10}Be and ^{26}Al from purified quartz and for extracting meteoric ^{10}Be from grain coatings on sediments and soils. Our *in situ* methods were adapted from those used at Lawrence Livermore National Laboratory and the University of Pennsylvania in the early 1990s and have evolved in what can best be described as punctuated equilibrium since then with significant contributions over two decades from the laboratories of J. Stone at the University of Washington and D. Fink in Australia. The flow on this procedure is most easily conveyed graphically (Fig. 1); the details are available at http://uvm.edu/cosmolab. The meteoric extraction method is based on the flux/fusion water extraction method of Stone (1998), which we have modified to include cation columns for boron reduction as well as a robust stand to improve the safety of the fluxing procedure (see facilities description). Below we focus on optimization we have conducted for *in situ* sample preparation. We have done but do not include here for reasons of space, a similar analysis for meteoric ^{10}Be processing.

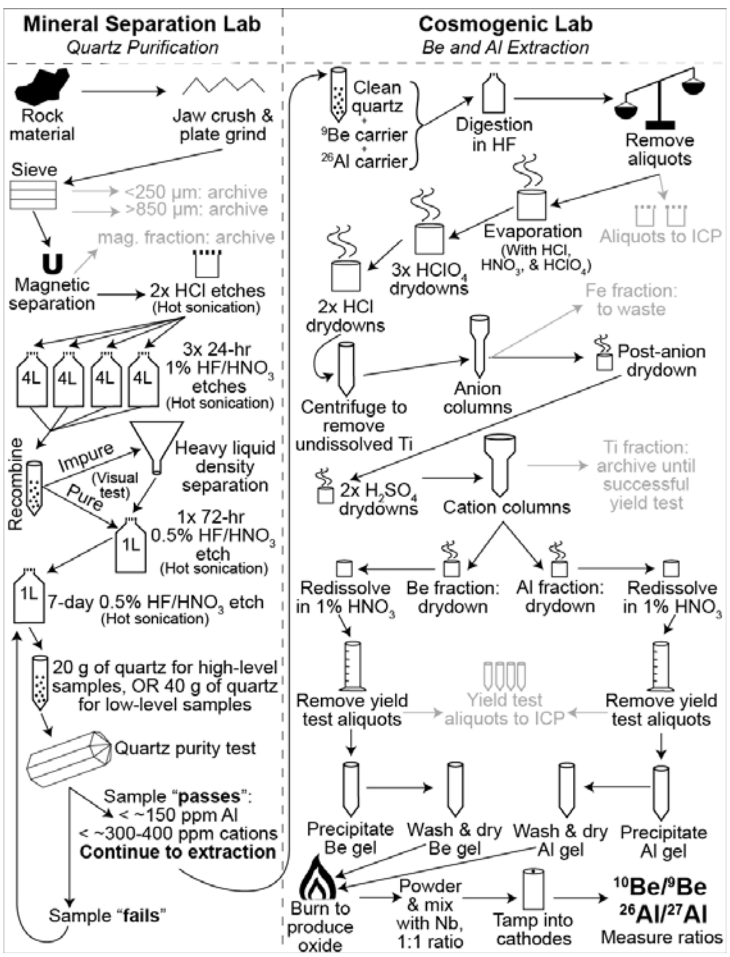

Figure 1. Flowchart describing the processes we employ, from beginning to end for the process of in situ ^{10}Be and ^{26}Al sample processing. This work is done, in sequence, in the rock room, mineral separation laboratory, and cosmogenic clean rooms.

Over the past 21 years, we have continually assessed and improved our sample preparation methodology implementing a variety of different quality control steps and optimizing our methods for safety, efficiency, and effectiveness (Bierman et al., 2002;

Hunt et al., 2006, 2007, 2008). Recent optimization efforts have focused on tracing Be throughout the extraction process (both after dissolution and after processing), producing high yields of pure Be (by optimizing column chromatography methods and quantifying quartz mineral separate purity), minimizing backgrounds (through reducing both laboratory process blanks and ^{10}B isobaric interference), and running quality control standards with every batch of samples. These optimization strategies increase the amount of ^{10}Be available for counting during accelerator mass spectrometry, while simultaneously decreasing interference and contamination, and ensuring that data are reproducible (Corbett et al., 2013b).

We trace beryllium in the sample at numerous points throughout the process, allowing us to both identify and correct for the presence of native beryllium (Portenga et al., 2015) and to monitor the final beryllium yield. Monitoring the final yield provides quality control, ensuring that beryllium is not lost during column chromatography or other steps (Hunt et al., 2008). We remove and analyze ICP-OES quality control aliquots two times during sample processing: once immediately after dissolution, then again just before final BeOH precipitation. Quality control data collected since 2009 shows that we effectively retain beryllium throughout the extraction process. The post-dilution samples retain 100.7 ± 2.1 % (n = 114, 1SD, process blanks only) of the beryllium added through carrier and the post-processing samples retain 94.0 ± 3.6 % (n = 114, 1SD, process blanks only), which represents an optimal yield since 6% of the sample mass is removed for the post-dissolution aliquots.

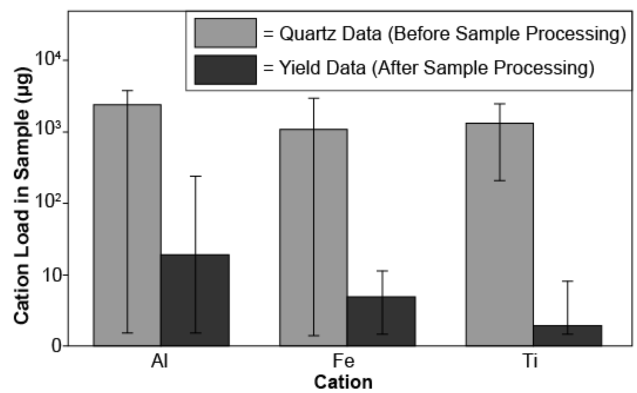

Figure 2. Final cation contents in samples compared to initial total cation contents in quartz (n = 797). Y-axis is in logarithmic scale.

Post-processing aliquots also serve as a quality check at the end of laboratory processing to verify that samples are ready for AMS analysis and provides quality control in a laboratory where many different people each year are extracting samples. Quantifying the Be yield determines if enough Be is present for a successful AMS measurement, while quantifying Be purity determines if the sample is free of common contaminants (e.g., Al, Fe, and Ti) known to interfere with AMS measurement (Hunt et al., 2008). When considered in reference to the quartz which was dissolved, laboratory treatment of Be fractions decreased average total sample Al contents by 99.1%, Fe contents by 99.5%, and Ti contents by 99.9% (n = 797, Fig. 2).

An additional focus of optimization in the University of Vermont laboratory has been column chromatography. We use an approach that adjusts the quartz mass based on the measured quartz purity in order to avoid overloading the column (which causes both beryllium loss and contamination of the beryllium fraction). The changes we have made to our column chromatography ensure that samples have consistently high beryllium yield and are free of contaminants (Al, Ti, and Fe) that interfere with AMS analysis (Hunt et al., 2008).

We recently (fall 2013) added a globally-recognized standard (Jull et al., 2015) to every batch of samples processed in the laboratory. These standards (Standard A and Standard N) come from the CRONUS Earth project and are either high- or low- ^{10}Be/^{9}Be, depending on the samples included in the batch. Each standard has a nominal value, allowing us to assess data

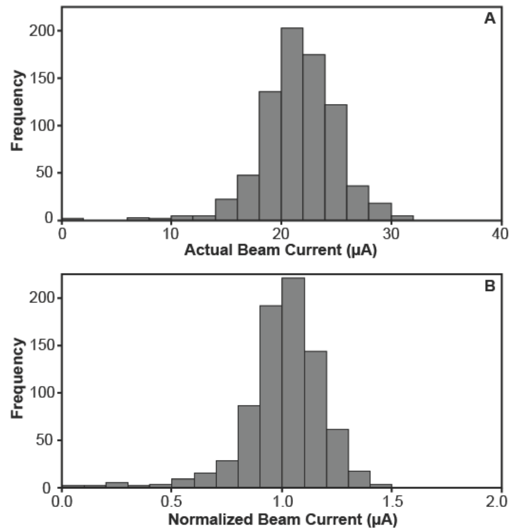

Figure 3. AMS $^{9}Be^{3+}$ beam currents (n = 797). Pannel A: Actual beam currents (μA) measured on the Lawrence Livermore National Laboratory AMS. Pannel B: Sample beam currents normalized to standard beam currents.

reproducibility and to place more realistic error bounds around measured $^{10}Be/^{9}Be$ values. We have now run CRONUS standards along with about 50 batches of samples.

The result of methodological advances made in the laboratory has been samples that run with consistently high $^{9}Be^{3+}$ beam currents on the Lawrence Livermore National Laboratory AMS. Over a multi-year study period (2009-2012), the average actual beam current for ^{10}Be samples prepared at the University of Vermont was 21.4 ± 3.8 μA (1 SD, n = 797). The beam current normalized to standards run with these samples was 1.0 ± 0.2 (1 SD, n = 797), indicating that the samples on average ran as well as the standards (Fig. 3).

We have worked to decrease ^{10}Be backgrounds in order to lower detection limits and enable to measurement of samples that are very young, long-buried, or have been subjected to very high erosion rates. To decrease laboratory blanks, especially for low $^{10}Be/^{9}Be$ samples, we use two fully separate processing streams with dedicated labware (high-level samples, $^{10}Be/^{9}Be > 10^{-13}$; and low-level samples, $^{10}Be/^{9}Be < 10^{-13}$). We use ^{9}Be carrier made in-house by the flux fusion of beryl (Stone, 1998) for all samples. Over the recent history of the laboratory, beryl blanks are lower (5.6 ± 3.2 x 10^{-16}, 1SD, n = 59) in the hood used to process low concentration samples and higher (9.0 ± 8.9 x 10^{-16}, 1SD, n = 29) in the hood used to process high concentration samples, demonstrating the effectiveness of maintaining separate processing streams and the exceptionally low blanks that are now routine for our sample processing.

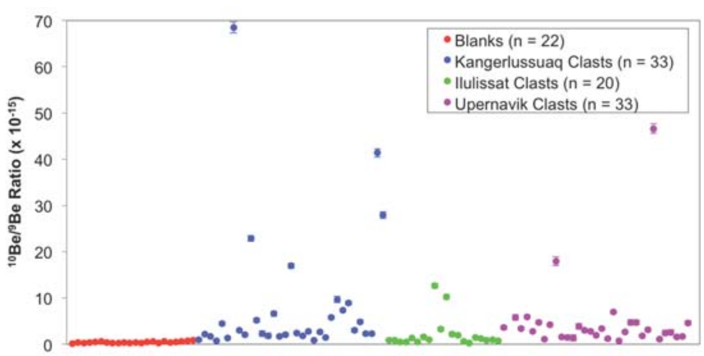

Figure 4. Data from 86 cobbles removed from three locations along the margin of the Greenland Ice Sheet. Average background $^{10}Be/^{9}Be$ ratio is 4.2 ± 1.6 x 10^{-16} (n = 24), making samples with as few as ~500 atoms g^{-1} measurable above blank (using 40 grams of pure quartz). Bars, where visible are 1 sigma counting statistics uncertainty.

The optimizations we have implemented make the University of Vermont sample preparation procedure robust to a wide variety of samples and projects. Since the purity of quartz varies significantly between sites, our approach allows us to adjust quartz mass accordingly and accommodate virtually all impurity levels. Further, our detection of native beryllium makes ^{10}Be analysis a viable technique even in areas where Be-bearing rocks (especially pegmatite) are present (Portenga et al., 2015). Finally, low backgrounds ensure that even samples containing very small amounts of ^{10}Be are measurable (Fig. 4). Furthermore, we routinely assess impurities and beryllium yield throughout the process to ensure the effectiveness of sample processing. Because the ICP-OES is nearby and is operated by PI Bierman and senior graduate students, quality control analysis happens in real-time.

5.3. Capacity

At present, the University of Vermont Cosmogenic Nuclide Laboratory operates below its full capacity during most times. Because we have two separate processing streams and separate hoods for digestion and column chromatography, we can process up to 900 samples per year in the *in situ* laboratory. Additionally, we can process ~700 samples per year in the separate meteoric laboratory. Although the University of Vermont Geomorphology group can at times have half a dozen graduate students, there are only isolated periods when both the *in situ* and meteoric laboratories operate at full capacity. The limit on the use of the laboratory is both the number of projects we have in house and Bierman's time to train and supervise students while teaching a full course load and doing his own research.

With a full time Lab Manager, the Vermont CNL has the capacity for visitors to process <u>an additional 400 to 500 samples per year.</u> The exact number will depend on the ratio of meteoric to in situ samples and the expected ^{10}Be concentration in the in situ samples.

5.4. Safety and Education

Because we have hosted visitors and trained students since the laboratory's inception, we have created a standardized training procedure that emphasizes both safety and an understanding of the lab methods that goes beyond cookbook-style instructions. Anyone working in the laboratory for the first time completes general on-line safety training required of anyone using hazardous materials at the University (http://esf.uvm.edu/courses/). Those working on cosmogenic sample preparation then receive a detailed safety orientation that includes information about personal protective equipment, chemical safety, and emergency response. Each trainee works one-on-one with either PI Bierman or a senior graduate student for several weeks to learn all aspects of the beryllium and aluminum extraction process, focusing on both the concepts and the execution. It is

Section 1 - Personnel capability checklist for laboratory procedures
PRODUCTION LABORATORY

During training, each person who will be working in the lab needs to complete this list with initials as they master skills and gain knowledge. Only after this list is complete, can a new user work alone in the lab.

NAME: ______________________________

	Item	Date	Personnel initial	Trainer initial
SAFETY /PROCEDURES INFORMATION	Understand the primary hazards associated with exposure to concentrated HF, $HCLO_3$, HCl, HNO_3, and Be. Have read MSDS for the chemicals we handle			
	Understand the proper personal protective gear to wear for each step in the laboratory.			
	When do you need to wear goggles?			
	Understand the meaning and importance of the blue, yellow and green sections of the lab.			
	Where is the first aid kit?			
	Where is the safety shower?			
	Where is the eyewash?			
	Know the meaning of red and yellow alarms.			
	Understand why we always use spill trays when pouring any chemicals.			
	Understand why any and all acid use must be done in a hood.			
	Know the safe working area of the hood deck.			
	Understand why the hoods and lab counters must be kept free of clutter.			
	Understand why unattended operation labels on the hoods and the vestibule are critical for safety			
	Understand why cleaning/cross talk prevention/ following the methods exactly are important for quality and safety.			
	Where do you find hot plate temperatures?			
	Where do you find cleaning instructions for lab			

Figure 5. Example page from the beryllium and aluminum extraction training log.

Table 1. Recent visitors to the University of Vermont Cosmogenic Nuclide Laboratory (U = undergraduate student, G = graduate student, and PD = post-doctoral researcher).				
Name	**Home Institution**	**Project Description**	**Visit**	**Resulting Peer-reviewed Publications**
Nicole West (G)	Penn State University	Meteoric ^{10}Be from Shale Hills Critical Zone	2 mo. 2009	West et al. (Applied Geochem., 2011) West et al. (J. Geophys. Res., 2013) West et al. (Geology, 2014)
Christine Regalla (G)	Penn State University	Meteoric ^{10}Be in sediments from Japan	3 mo. 2009, 2010	Regalla et al. (Geomorphology, 2013)
Em Perry (U)	Williams College	In situ ^{10}Be in Madagascar and Colorado sediment	2 mo. 2010	Cox et al. (paper in preparation, GSA Abstract, 2010)
Allan Bacon (G)	Duke University	Meteoric ^{10}Be in piedmont soil	1 mo. 2011	Bacon et al. (Geology, 2012)
James McCarthy (U&G)	Williams College and U. Toronto	In situ ^{10}Be in Peru Argentina, Colorado sediment	2 mo, 2011, 2013	Wyshnytzky et al. (Catena, 2015) Dethier et al. (Geology, 2014) McCarthy et al. (JGR., *in review)*
Eric Portenga (G)	University of Glasgow	In situ ^{10}Be in Australian sediment	2 mo. 2013	Portenga et al. (Ear. Planet. Sci. Let., *in review-a*) Portenga et al. (Geology, *in review-b*)
Fabiano Pupim (G)	Federal University of Brazil	In situ ^{10}Be in sediment from Brazil	6 mo. 2013	Pupim et al. (Geomorphology, 2015)
Devin McPhillips (PD)	Syracuse University	In situ ^{10}Be in sediments from Peru and Tibet	3 mo. 2013, 2014	McPhillips et al. (J. Geophys. Res., 2013) McPhillips et al. (Nature Geosci., 2014) McPhillips et al. (GRL., *in review*)
Neil Shea (G)	University of Connecticut	In situ and meteoric ^{10}Be in Colorado sediment	6 mo. 2014	Ouimet et al. (Quaternary Sci. Rev., 2015)
Lisa Luna (U)	Middlebury College	In situ ^{10}Be in balanced rocks from New Zealand	2 mo. 2014	Rood et al. (BSSA, in preparation)
Adrian Bender (G)	Western Washington University	Burial isochrons for seismic hazard, Washington	4 mo. 2014	Bender et al. (J. Geophys. Res., *in review*)
Allie Koestera (G)	Boston College	In situ ^{10}Be for New England deglaciation	4 mo. 2015	Project in progress

because our training process is so extensive that we have been unable to support more than one or two visitors a year.

The training procedures we use are standardized to ensure that all students working in the laboratory, both from University of Vermont and elsewhere, receive the same level of training. Each trainer/trainee pair maintains a training log (Fig. 5) containing detail about each step of the process which both parties initial only after the trainee is able to complete the process safely and reproducibly.

5.5. Past Experience – Success of Prior Visitors to the University of Vermont CNL

Since the new laboratory opened in 2009, the University of Vermont CNL has consistently hosted visitors working on collaborative projects and we have a track record of success (Table 1). Because of limited resources, particularly the time of laboratory trainers, we have been unable to host more than several visitors each year. These visitors, however, have successfully mastered the methods, produced high quality data, and their work has resulted in numerous collaborative publications in high-profile, peer reviewed journals.

6. Work Plan - Proposed National Facility for Hands on Cosmogenic Sample Preparation

With support from NSF, we propose to open to the community, for the purpose of ^{10}Be and ^{26}Al sample preparation, the long-standing University of Vermont CNL. *Our overall goal is catalyze better and more varied isotope geoscience with the potential to generate transformative impacts by increasing the number of samples that can be prepared, the diversity of scientists involved, and thus the variety of cosmogenic nuclides applications in the geosciences*. On the ground, this translates to providing additional sample processing capacity and increasing the breadth of scientists working with these isotopic systems - needs specifically identified by the geochronology community (Harrison et al., 2015).

To achieve this overarching goal, we have designed our work plan to meet three specific, assessable goals.

GOAL 1. We seek to <u>provide opportunities</u> for those students, faculty, and postdoctoral researchers without a cosmogenic laboratory at their home institution to learn cleanroom geochemical techniques so that they can then prepare their own samples.

GOAL 2. We seek to <u>broaden participation</u> in cosmogenic isotope geology for populations currently under-represented in the geosciences using campus visits and a seed grant program.

GOAL 3. We seek to <u>introduce undergraduate students</u> to the power of cosmogenic isotopes in Earth Science so that they can develop connections with labs and personnel, discover research possibilities, and are exposed techniques they can pursue at the graduate level.

In the subsections that follow, we describe specifically how we plan to achieve each of these three goals. We propose a budget that requests resources specific to each of these goals as well as resources to conduct formative assessment so we can make mid-course corrections as needed and conduct summative assessment to determine if we have met our goals by completion of the grant.

Critical to the project is support of a fulltime Laboratory Manager, a Ph.D.-level scientist, Ms. Lee Corbett. She will direct laboratory education and outreach activities collaboratively with Laboratory Director, Bierman. Corbett's primary responsibilities will be the training of all visitors, ensuring safety in the laboratory, tracking laboratory quality control data, and directing outreach to the broader geoscience community. She and Bierman will collaborate on projects with visitors, providing expertise as is appropriate in regards to sampling, data reduction, and data interpretation. We feel strongly that visitors will be best served by a Laboratory Manager at the doctoral level because extensive and deep understanding of not only laboratory procedures but of cosmogenic nuclide systematics is prerequisite to ensuring that visitors receive consistent, high-level training in safe, reproducible, and optimized methods.

6.1. GOAL 1 - Providing opportunities for those without laboratories to prepare samples

With a full time laboratory manager, supported by NSF, we will be able to routinely open the University of Vermont CNL to students, faculty, and post-doctoral researchers. This accessibility makes cosmogenic nuclide science possible for scientists who do not have a clean laboratory or even a quartz-preparation laboratory on campus. Not only will a national facility make sample preparation capabilities more widely available, it will demystify the process – taking away the black box of sending samples off to be processed by others. Because of our history in hosting small numbers of visitors (Table 1), we have a pre-existing framework for visitor logistics and know well how to help them adapt to life in Burlington and in the laboratory. With an NSF-supported Laboratory Manager, not only will visitor numbers greatly increase but the pedagogical quality of the visitor experience will improve significantly.

Visitors to the CNL will engage in either one or both phases of sample preparation for ^{10}Be and ^{26}Al, depending on the resources available at their home institution: isolation of pure quartz and extraction of beryllium (and aluminum, if it is part of the project). Visit duration will depend on the number of samples to be analyzed and how much initial preparation work (crushing, sieving) could be done at their home institution, but visits could range from several weeks to several months. Visitors will pay the nominal per-sample fee for laboratory consumables (currently set on a cost recovery basis at $40/sample for quartz preparation and $150/sample for ^{10}Be/^{26}Al extraction), but no additional cost for training or supervision in the laboratory. We will work with visitors to arrange for temporary housing; they would cover the cost of such housing.

Visitors will work one-on-one with Lab Manager Corbett in all steps of their training and while processing samples. We will continue to use training logs (Fig. 5) to document visitor learning and to ensure that every visitor receives consistent, high quality training. We will maintain the three-step training protocol that we currently use in the laboratory:

1. The first time a user performs a procedure, the trainer demonstrates how to execute the steps safely and correctly and talks through the rationale of why each step exists.
2. The second time the user performs a procedure, he/she conducts the hands-on work with the trainer talking him/her through the steps and watching the entire procedure to ensure that it is done safely and correctly.
3. The third time the user performs a procedure, he/she conducts the hands-on work, with the trainer watching at least the first sample and being readily available for questions and check-ins throughout.

In addition to providing support for the analysis of samples, the University of Vermont Geomorphology research group (http://uvm.edu/geomorph) will provide a platform for presentation and discussion of the visitor's work. Each visitor will deliver a short, informal presentation to faculty and graduate students describing their project design and goals. These informal talks would provide an opportunity for the visitor to receive feedback about their work and would foster collaboration between University of Vermont and other institutions.

Visitors can reach Burlington easily by car, bus, rail, or plane. Burlington is a college town of about 40,000 residents and hence has ample reasonably-priced options for housing and dining. Because campus is located close to downtown, visitors would not need a vehicle. We have temporary office space, computing facilities, and broadband access available for visitors during their stay.

There is clear and demonstrated need of the facility we propose. Prior to and during preparation of this proposal, we contacted some of our colleagues and explained the facility we envisioned and its mission. Table 2 lists those who responded supporting this initiative and would either come as visitors or send students to work in the University of Vermont CNL. Given the community interest in ^{10}Be and ^{26}Al, we suspect there are many others who would also make use of the facility.

Table 2. Faculty who have expressed interest in this proposal and in sending students to train and process samples at University of Vermont.

Name	**Position**	**Home Institution**
Jeremy Shakun	Assistant Professor	Boston College
Christine Regalla	Assistant Professor	Boston University
Eric Kirby	Associate Professor	Oregon State University
Dave Dethier	Professor	Williams College
Will Ouimet	Assistant Professor	University of Connecticut
Sarah Principato	Associate Professor	Gettysburg College
Amanda Schmidt	Assistant Professor	Oberlin College
Richard K. Dunn	Professor	Norwich University
Devin McPhillips		
More to come…I sent emails to about 20 people Friday afternoon		

6.2. GOAL 2 - Broaden participation in cosmogenic isotope geology, campus visits and the Seed Grant Program

Geoscience, specifically cosmogenic geoscience, remains primarily a white, male endeavor. For example, O'Connell and Holmes (2011) report that"…between 2000 and 2008, underrepresented minorities earned 16%–17% of STEM degrees and only 5%–7% of geoscience degrees". We seek to actively change that model using outreach visits to campuses and a seed grant program that will bring students and faculty together with Vermont experts to conduct cosmogenic isotope science both in the field and the laboratory. Our approach involves proactive outreach to HBCUs and TCs. Initial contact will be made based on contacts provided by consultants Semken and Whittaker. We seek to make lasting impacts by building on-going collaborative relationships with both faculty and students and by providing technical and pedagogic information, useful for teaching, advising, and jump-starting faculty.

During each summer, we will reach out to deans and STEM faculty at a variety of institutions serving those under-represented in the geosciences and determine which institutions would be interested in a two-day visit by Bierman or Corbett during the fall and supported by this proposal. On the first day of the visit, we will teach a short course showing how cosmogenic isotopes can be used to solve a variety of STEM problems and linking these isotopes to students' knowledge of chemistry, physics, engineering, and environmental science. The course will have a significant hands-on component, targeting faculty and students in Chemistry, Engineering, and Environmental Science because few HBCUs and TCs have Geoscience departments. On the second day, we will meet with students, faculty and deans both in small groups and one on one to discuss our facility, the seed grant program, and options for collaborative science. Each year, we will each travel to three schools.

In the winter, we will solicit seed grant proposals from interested faculty/student pairs. Together, Bierman, Corbett, Semken, and Whittaker will select two proposals from the pool based on both scientific merit and potential for transformative experiences for the student and faculty member. Supportable projects will involve the use of cosmogenic nuclides to solve a geoscience problem of relevance to the faculty and region; field areas will be located in proximity to the applicant's campus. These seed grants will provide all analytical costs for 10 samples including sample preparation materials and AMS analysis; they will provide a stipend of $400 to the student to cover time they will spend working on the project (and not otherwise working). Fieldwork will be done early in the summer and sample processing completed later the same summer. Bierman or Corbett will be supported by this proposal to collaborate in fieldwork. Travel of the student/advisor pair to Vermont, as well as living expenses while on campus, will be supported so that together they can participate in sample preparation, learning cleanroom techniques as a team. AMS data should be ready in the fall and then collaboration will continue by email and Skype between Vermont scientists and the awardees. We anticipate early winter collaborative preparation of an abstract for the appropriate regional GSA meeting (to which we will offer a student travel and registration stipend). Ideally, data will result in a joint publication led by the student/faculty pair and assisted by Corbett and/or Bierman.

By engaging STEM undergraduate students relatively early in their careers, such students are more likely to continue to graduate work (Hurtado et al., 2014), and after participating in the proposed program they will have significant research and laboratory experience making them more appealing applicants. The partnering faculty members will gain knowledge about a new technique that they could utilize as a teaching tool and in further research proposals to NSF in both core programs and those targeted at institution serving those under-represented in the STEM disciplines.

6.3. GOAL 3 – Use campus visits to introduce students at Primarily Undergraduate Institutions to the power of isotopes and provide a facility in which they can learn isotope science

For many geochronologic techniques, including cosmogenic nuclides, research and research training opportunities are often limited to faculty and graduate students at research-intensive institutions. Some faculty and students at PUIs are unaware of the power of isotope geology to solve research problems while others cannot participate in this type of research because they lack the appropriate facilities. As a result, most faculty and students at PUI's have little exposure to and even less experience with cosmogenic nuclides. The need for specialized facilities effectively excludes from isotope geoscience a large population of students and faculty who attend or teach at undergraduate institutions. Furthermore, because students under-represented in geoscience are more common (Wilson, 2014) at the undergraduate (7%) than at the Masters (5%) or doctoral levels (2%), outreach to undergraduate students and faculty can provide exposure to methods and research experiences that often prompt students from under-represented groups to stay in science (Hurtado et al., 2014),. Likewise, faculty at PUIs, many of whom come from research-intensive graduate programs, now lack access to geochronologic facilities for their own research.

Parallel to the visitation program we describe to address GOAL 2, we propose a similar, but regionally focused, outreach program involving two-day campus visits to PUIs. Each year, Bierman or Corbett will make three trips to PUIs in the northeastern United States. We will present a short course (on a weekend day or in two consecutive evenings) on cosmogenic isotopes and then spend a day interacting with faculty, students and administrators. The goal of our visits will be to both introduce students to the power of cosmogenic systems and to discuss with faculty the potential for collaboration and for their students to spend time as visitors processing samples at the Vermont CNL.

6.4 Program timeline and details

We propose a three-year proof of concept (fall 2016 through summer 2019) that would allow us to refine our approach and assess success of the program. Based on informal sampling and prior experience, we expect enthusiastic participation from the community, development of numerous new collaborative relationships, and training 15-20 visitors (including students, faculty and post-doctoral researchers) in transferable laboratory skills. If the program is successful and there is sustained community interest, we will seek renewed funding in order to continue making cosmogenic nuclide analysis accessible to students without laboratories at their home institutions.

Start-Up Phase: September 2016-December 2016

During the first six months of the project, we will upscale laboratory operations in preparation for an eventual doubling of sample throughput and we will heavily advertise the availability of the facility to the community. We will move to a database structure for all laboratory data, continue to streamline laboratory methods, and create web-based displays of quality control data in near live time. We will solicit participation from interested students and faculty by advertising the program at scientific meetings by travelling to AGU and doing a pop up at Gilbert Club and by travelling to GSA and speaking at the QGG business meeting. We will send notices to relevant geographic and geologic list serves, develop and print brochures, and reach out to tribal colleges and HBCUs with phone calls and emails. During this phase, Bierman and Corbett with work with Semken to develop formative assessment tools including pre and post surveys we will administer at all short courses and to all laboratory visitors. These will be electronic so as to remove transcription costs and reduce the time needed to collate data.

Visiting Student Program In Operation: January 2017 – July 2019

The first student visitors will arrive in early 2017, with stays of several weeks to several months depending on their scientific needs. The program will continue, with an average of six visitors per calendar year. Student visitation schedules would be flexible and mutually agreed upon between the hosts and visitors.

Seed Grant Cycles

We will request Seed Grant proposals in January, make decision in February, do fieldwork in early summer and complete analyses by summer's end. There will be three cycles: 2017, 2018, and 2019.

Summative Assessment: Summer 2019

After 2.5 years in operation, Semken will summatively assess the effectiveness of the program and the level of community interest and participation. NEED MORE WORDS FROM STEVE.

7. Intellectual Merit

We propose here a new model for isotope geoscience: a community sample preparation facility. Building upon established protocols, we will catalyze research and research training by increasing access to ^{10}Be and ^{26}Al sample preparation. Providing a national sample preparation facility will bring new and different scientists into the isotope geoscience community, increasing not only the number but also the diversity of projects involving these isotopes. Bringing in new ideas, especially from researchers with different areas of expertise and backgrounds, will spur the development of new approaches and applications – a catalyst for transformative research.

Because the methods used in the University of Vermont CNL can accommodate a wide range of project goals, particularly through low backgrounds and ICP-OES quantification of both beryllium and aluminum, novel projects and under-utilized techniques will become more accessible to the broader community. This is especially true for projects investigating samples with very low $^{10}Be/^{9}Be$ (i.e. very young, long-buried, or rapidly-eroding samples), those in areas where rocks contain significant native Be (Portenga et al., 2015), and those utilizing ^{26}Al as well as ^{10}Be (Granger, 2006), including burial isochron dating (Balco and Rovey, 2008).

8. Broader Impacts

Ours is a new approach aimed at broadening participation in the expanding field of cosmogenic isotope geoscience by opening a long-recognized laboratory to the community. The development of a community sample preparation facility will have numerous broader impacts.

- This facility directly <u>addresses a current bottleneck</u> in cosmogenic nuclide geoscience: the extraction of beryllium and aluminum from rock, soil, and sediment that precedes isotopic measurement, a need clearly pointed out in a recent NSF report (Harrison et al., 2015).
- A community facility will <u>democratize the use of cosmogenic nuclides</u> by providing access to a state-of-the art sample processing facility. Due to the cost and complexity of building and maintaining isotope geoscience laboratories, students and faculty at TCs, HBCUs, and PUIs rarely have access to such facilities. This proposal will provide an open, shared facility along with dedicated instruction and mentoring for interested students and faculty.
- Our outreach program goes directly to faculty and students at institutions <u>serving communities under-represented in the geosciences</u> and our seed grant program brings faculty/student teams to the laboratory for meaningful collaboration and hands-on training. By involving faculty, students, and administrators at TCs and HBCUs, we will work to build long-lasting faculty collaborations, provide the basis for faculty to apply for NSF support directly, and establish a pathway to graduate school for undergraduate students.
- Facility support will provide dedicated, <u>hands-on research training</u> in clean lab methods for students, researchers, and faculty in a variety of geoscience disciplines. Knowledge gained by the visitors during their time at Vermont will be highly transferable. Their training will encompass laboratory safety, basic laboratory techniques, cleanroom procedures, quality control assessment, and ICP-OES analysis, skills that can be transferred to laboratories at their home institutions and to future careers. Quantitative skills gained through data analysis will be transferable to any career, within the STEM disciplines and beyond

References Cited

Bacon, A.R., Richter, D., Bierman, P.R., and Rood, D.H., 2012, Coupling meteoric ^{10}Be with pedogenic losses of ^{9}Be to improve soil residence time estimates on an ancient North American interfluve: Geology, v. 40, no. 9, p. 847-850.

Balco, G., 2011, Contributions and unrealized potential contributions of cosmogenic-nuclide exposure dating to glacier chronology, 1990-2010: Quaternary Science Reviews, v. 30, no. 1-2, p. 3-27.

Balco, G., Purvance, M.D., and Rood, D.H., 2011, Exposure dating of precariously balanced rocks: Quaternary Geochronology, v. 6, no. 3-4, p. 295-303.

Balco, G., and Rovey, C., 2008, An isochron method for cosmogenic-nuclide dating of buried soils and sediments: American Journal of Science, v. 308, p. 1083-1114.

Bard, E., Raisbeck, G., Yiou, F., and Jouzel, J., 2000, Solar irradiance during the last 1200 years based on cosmogenic nuclides: Tellus, v. 52B, p. 985-992.

Behr, W.M., Rood, D.H., Fletcher, K.E., Guzman, N., Finkel, R., Hanks, T.C., Hudnut, K.W., Kendrick, K.J., Platt, J.P., Sharp, W.D., Weldon, R.J., and Yule, J.D., 2010, Uncertainties in slip rate estimates for the Mission Creek strand of the southern San Andreas fault at Biskra Palms Oasis, southern California: Geological Society of America Bulletin, v. 122, no. 9-10, p. 1360-1377.

Bender, A.M., Amos, C.B., Bierman, P.R., Rood, D.H., Staisch, L., Kelsey, H., and Sherrod, B., *in review*, Differential uplift and incision of the Yakima River terraces: Journal of Geophysical Research Solid Earth.

Bierman, P., Amidon, W., Balco, G., Briner, J., Fifield, L.K., Hall, B., Larsen, I., Rood, D., Schaefer, J., Southon, J., Steig, E., and Stone, J., 2015, Optimizing the next generation of AMS for measuring ^{10}Be and ^{26}Al: NSF-Sponsored Workshop Report, http://www.uvm.edu/cosmolab/FINAL_AMS_white_paper_1_25_15.pdf.

Bierman, P.R., Caffee, M.W., Davis, P.T., Marsella, K., Pavich, M., Colgan, P., Mickelson, D., and Larsen, J., 2002, Rates and timing of Earth surface process from *in situ*-produced cosmogenic Be-10: Reviews in Mineralogy and Geochemistry, v. 50, no. 1, p. 147-205.

Bierman, P., Corbett, L., Graly, J., Neumann, T., Lini, A., Crosby, B., and Rood, D., 2014, Preservation of a preglacial landscape under the center of the Greenland Ice Sheet: Science, v. 344, p. 402-405.

Bierman, P., Davis, P., Corbett, L., and Lifton, N., *in review*, Cold-based, Laurentide ice covered New England's highest summits during the Last Glacial Maximum: Geology.

Bierman, P., Marsella, K., Patterson, C., Davis, P., and Caffee, M., 1999, Mid-Pleistocene cosmogenic minimum-age limits for pre-Wisconsinan glacial surfaces in southwestern Minnesota and southern Baffin Island: a multiple nuclide approach: Geomorphology, v. 27, no. 1, p. 25-39.

Corbett, L., Bierman, P., and Davis, P., *in review-a*, Glacial history and landscape evolution of southern Cumberland Peninsula, Baffin Island, Canada, constraining by cosmogenic ^{10}Be and ^{26}Al: Geological Society of America Bulletin.

Corbett, L., Bierman, P., Graly, J., Neumann, T., and Rood, D., 2013a, Constraining landscape history and glacial erosivity using paired cosmogenic nuclides in Upernavik, northwest Greenland: Geological Society of America Bulletin, v. 125, no. 9/10, p. 1539-1553.

Corbett, L., Bierman, P., Lasher, G., and Rood, D., 2015, Landscape chronology and glacial history in Thule, northwest Greenland: Quaternary Science Reviews, v. 109, p. 57-67.

Corbett, L., Bierman, P., and Reusser, L., 2011a, Incorporating concept sketching into teaching undergraduate geomorphology: Geological Society of America Abstracts with Programs, v. 43, no. 1, p. 142.

Corbett, L., Bierman, P., and Rood, D., 2013b, Optimizing sample preparation for high-precision, low-detection limit analysis of in situ ^{10}Be: strategies and new data: Geological Society of America Abstracts with Programs, v. 45, no. 7, p. 118.

Corbett, L., Bierman, P., and Rood, D., *in review-b*, Constraining multi-stage exposure-burial scenarios for boulders preserved beneath cold-based glacial ice in Thule, northwest Greenland: Earth and Planetary Science Letters.

Corbett, L., and West, D., 2012, Concepts of space and time: important take-home messages for non-geology students in a geology course: Geological Society of America Abstracts with Programs, v. 44, no. 2, p. 44.

Corbett, L., Young, N., Bierman, P., Briner, J., Neumann, T., Graly, J., and Rood, D., 2011b, Paired bedrock and boulder ^{10}Be concentrations resulting from early Holocene ice retreat near Jakobshavn Isfjord, western Greenland: Quaternary Science Reviews, v. 30, p. 1739-1749.

Cox, R., Bierman, P.R., Perry, E.O., and Rakotondrazafy, A.F.M., 2010, Cosmogenic ^{10}Be analysis of river sands provides background erosion rates for Madagascar: Geological Society of America Abstracts with Programs, v. 42, no. 5, p. 418.

Davis, P., Bierman, P., Corbett, L., and Finkel, R., 2015, Cosmogenic exposure age evidence for rapid Laurentide deglaciation of the Katahdin area, west-central Maine, USA, 16 to 15 ka: Quaternary Science Reviews, v. 116, p. 95-105.

Dethier, D.P., Ouimet, W., Bierman, P.R., Rood, D.H., and Balco, G., 2014, Basins and bedrock: Spatial variation in ^{10}Be erosion rates and increasing relief in the southern Rocky Mountains, USA: Geology, v. 42, no. 2, p. 167-170.

Erlanger, E.D., Granger, D.E., and Gibbon, R.J., 2012, Rock uplift rates in South Africa from isochron burial dating of fluvial and marine terraces: Geology, v. 40, p. 1019-1022.

Fabel, D., and Harbor, J., 1999, The use of in-situ produced cosmogenic radionuclides in glaciology and glacial geomorphology: Annals of Glaciology, v. 28, no. 1, p. 103-110.

Gosse, J. C., and Phillips, F.M., 2001, Terrestrial in situ cosmogenic nuclides: theory and application: Quaternary Science Reviews, v. 20, p. 1475-1560.

Graly, J., Bierman, P.R., Reusser, L.J., and Pavich, M.J., 2010, Meteoric ^{10}Be in soil profiles- A global meta-analysis: Geochimica et Cosmochimica Acta, v. 74, no. 23, p. 6814-6829.

Graly, J., Reusser, L.J., and Bierman, P.R., 2011, Short and long-term delivery rates of meteoric ^{10}Be to terrestrial soils: Earth and Planetary Science Letters, v. 302, no. 3-4, p. 329-336.

Granger, D., 2006, A review of burial dating methods using ^{26}Al and ^{10}Be: Geological Society of America Special Papers, v. 415, p. 1-16.

Granger, D., Lifton, N.A., and Willenbring, J.K., 2013, A cosmic trip: 25 years of cosmogenic nuclides in geology: Geological Society of America Bulletin, v. 125, no. 9-10, p. 1379-1402.

Harrison, T.M., Baldwin, S.L., Caffee, M., Gehrels, G.E., Schoene, B., Shuster, D.L., and Singer, B.S., 2015, It's About Time: Opportunities and Challenges for U.S. Geochronology: Institute of Geophysics and Planetary Physics Publication 6539, University of California, Los Angeles, 56 pp.

Hunt, A., Larsen, J., Bierman, P., and Petrucci, G., 2008, Investigation of factors that affect the sensitivity of accelerator mass spectrometry for cosmogenic ^{10}Be and ^{26}Al isotope analysis: Analytical Chemistry, v. 80, p. 1656-1663.
Hunt, A.L., Petrucci, G.A., Bierman, P.R., and Finkel, R.C., 2006, Metal matrices to optimize ion beam currents for accelerator mass spectrometry: Nuclear Instruments and Methods in Physics Research B, v. 243, p.216-222.
Hunt, A.L., Petrucci, G.A., Bierman, P.R., and Finkel, R.C., 2007, Investigation of metal matrix systems for cosmogenic ^{26}Al analysis by accelerator mass spectrometry: Nuclear Instruments and Methods in Physics Research B, v. 243, p.216-222.
Hurtado et al., 2014 – NEED TO COMPLETE REFERENCE
Jull, A.J.T., Scott, E.M., and Bierman, P., 2015, The CRONUS-Earth inter-comparison for cosmogenic isotope analysis: Quaternary Geochronology, v. 26, p. 3-10.
McCarthy, J.A., Schoenbohm, L.M., Bierman, P.R., Rood, D., and Hidy, A.J., *in review*, Late Quaternary Tectonics, Incision, and Landscape Evolution of the Calchaquí River Catchment, Eastern Cordillera, NW Argentina: Journal of Geophysical Research Earth Surface.
McPhillips, D., Bierman, P., and Rood, D., 2013, Landscape response to Pleistocene-Holocene precipitation changes in the Western Cordillera, Peru: ^{10}Be concentrations in modern and terrace sediments: Journal of Geophysical Research Earth Surface, v. 118, no. 4, p. 2488-2499.
McPhillips, D., Bierman, P., and Rood, D., 2014, Millennial-scale record of landslides in the Andes consistent with earthquake trigger: Nature Geoscience, v. 7, p. 925-930.
McPhillips, D., Hoke, G.D., Liu-Zeng, J., Bierman, P.R., Rood, D.H., and Niedermann, S., *in review*, Incision of the Yangtze River Gorge at the First Bend determined by three-nuclide burial dating: Geophysical Research Letters.
Mifsud, C., Fujioka, T., and Fink, D., 2013, Extraction and purification of quartz in rock using hot phosphoric acid for in situ cosmogenic exposure dating: Nuclear Instruments and Methods in Physics Research B: Beam Interactions with Materials and Atoms, v. 294, p. 203-207.
Mitchell, S., Matmon, A., Bierman, P., Enzel, Y., Caffee, M., and Rizzo, D., 2001, Displacement history of a limestone normal fault scarp, northern Israel, from cosmogenic ^{36}Cl: Journal of Geophysical Research Solid Earth, v. 106, no. B3, p. 4247-4264.
Nichols, K., Bierman, P., Caffee, M., Finkel, R., and Larsen, J., 2005, Cosmogenically enabled sediment budgeting: Geology, v. 33, no. 2, p. 133-136.
O'Connell, S., & Holmes, M. A. (2011). Obstacles to the recruitment of minorities into the geosciences: A call to action. *GSA Today*, *21*(6), 52-54. CHECK THIS FORMAT
Ouimet, W., Dethier, D., Bierman, P., Wyshnytsky, C., Shea, N., and Rood, D., 2015, Spatial and temporal variations in meteoric 10Be inventories and long term deposition rates, Colorado Front Range: A cautionary tale: Quaternary Science Reviews, v. 109, p. 1-12.
Portenga, E., and Bierman, P., 2011, Understanding Earth's eroding surface with ^{10}Be: GSA Today, v. 21, no. 8, p. 4-10.
Portenga, E. W., Bishop, P., Rood, D. H., and Bierman, P. R., *in review-a*, Retrospectively identifying initiation sites of erosion gullies using meteoric ^{10}Be and bulk sediment optically stimulated luminescence: Earth and Planetary Science Letters.

Portenga, E. W., Rood, D. H., Bishop, P. and Bierman, P. R., *in review-b*, Isotopic evidence for a mid-Holocene landscape response to Aboriginal burning in southeastern Australia: Geology.

Portenga, E., Bierman, P., Duncan, C., Corbett, L., Kehrwald, N., and Rood, D., 2015, Erosion rates of the Bhutanese Himalaya determined using in situ-produced ^{10}Be: Geomorphology, v. 233, p. 112-126.

Pupim, F.N., Bierman, P.R., Assine, M.L., Rood, D.H., Silva, A., and Merino, E.R., 2015, Erosion rates and landscape evolution of the Upper Paraguay river basin (Brazil) from cosmogenic ^{10}Be: Geomorphology, v. 234, p. 151-160.

Regalla, C., Kirby, E., Fisher, D., and Bierman, P., 2013, Erosional response to active shortening in the Tohoku forearc, NE Honshu, Japan: Geomorphology, v. 195, p. 84-98.

Reusser, L., Corbett, L., and Bierman, P., 2012, Incorporating concept sketching into teaching undergraduate geomorphology: Journal of Geoscience Education, v. 60, p. 3-9.

Stone, J., 1998, A rapid fusion method for separation of beryllium-10 from soils and silicates: Geochimica et Cosmochimica Acta, v. 62, no. 3, p. 555-561.

von Blanckenburg, 2005, The control mechanisms of erosion and weathering at basin scale from cosmogenic nuclides in river sediment: Earth and Planetary Science Letters, v. 237, no. 3-4, p. 462-479.

von Blanckenburg, F., Bouchez, J., and Wittman, H., 2012, Earth surface erosion and weathering from the ^{10}Be(meteoric)/^{9}Be ratio: Earth and Planetary Science Letters, v. 351-352, p. 295-305.

West, N., Kirby, E., and Bierman, P., 2011, Preliminary estimates of regolith generation and mobility in the Susquehanna Shale Hills Critical Zone Observatory, Pennsylvania, using meteoric ^{10}Be: Applied Geochemistry, v. 26, p. S146-S148.

West, N., Kirby, E., Bierman, P., and Clarke, B., 2014, Aspect-dependent variations in regolith creep revealed by meteoric ^{10}Be: Geology, v. 42, no. 6, p. 507-510.

West, N., Kirby, E., Bierman, P., Slingerland, R., Ma, L., Brantley, S., and Rood, D., 2013, Regolith production and transport at the Susquehanna Shale Hills Critical Zone Observatory, Part 2: Insights from meteoric ^{10}Be: Journal of Geophysical Research Earth Surface, v. 118, no. 3, p. 1877-1896.

Willenbring, J.K., and von Blanckenburg, F., 2010, Meteoric cosmogenic Beryllium-10 adsorbed to river sediment and soil: Applications for Earth-surface dynamics: Earth-Science Reviews, v. 98, no. 1-2, p. 105-122.

Wilson, C., 2014, Status of recent geoscience graduates, American Geosciences Institute, 42 pp.

Wittmann, H., von Blanckenburg, F., Bouchez, J., Dannhaus, N., Naumann, R., Christl, M., and Gaillardet, J., 2012, The dependence of meteoric ^{10}Be concentrations on particle size in Amazon River bed sediment and the extraction of reactive ^{10}Be/^{9}Be ratios: Chemical Geology, v. 318-319, p. 126-138.

Wyshnytzky, C., Ouimet, W.B., McCarthy, J. A., Dethier, D.P, Shroba, R.R., and Bierman, P.R., 2015, Meteoric Be-10, clay, and extractable Fe depth profiles in the Colorado Front Range: Implications for soil mixing and slope stability: Catena, v. 127, p. 32–45.

Young, N., Briner, J., Rood, D., Finkel, R., Corbett, L., and Bierman, P., 2013, Age of the Fjord Stade moraines in the Disko Bugt region, western Greenland, and the 9.3 and 8.2 ka cooling events: Quaternary Science Reviews, v. 60, p. 76-90.

Zimmerman, S., Finkel, R.C., and Brown, T.A., 2014, High precision ^{10}Be dating: A community effort: Goldschmidt 2014 Abstracts, p. 2875.

Paul R. Bierman, Professor of Geology and Cosmogenic Isotope Laboratory Director
Department of Geology and School of Natural Resources, University of Vermont

(i) Professional Preparation

BA, 1985, Geology and Environmental Studies, Williams College, Williamstown, MA
"*Deglaciation of Northwestern Massachusetts*" (cum laude and senior thesis)

MS, 1990, Geology, University of Washington, Seattle, WA with A. Gillespie
"*Accuracy and Precision of Rock Varnish Cation Ratio Dating*"

Ph.D., 1993, Geology, University of Washington, Seattle, WA with A. Gillespie
"*Cosmogenic Isotopes and the Evolution of Granitic Landforms*"

(ii) Appointments

2002-present	Professor	Univ. Vermont, Geology and Natural Resources
1998-2002	Associate Professor	Univ. Vermont, Geology and Natural Resources
1993-1998	Assistant Professor	Univ. of Vermont
1992-1993	Lecturer	University of Washington
1993	Visiting Researcher	University of Adelaide
1987-1992	Research and Teaching Assistant	University of Washington

(iii) Products

(a) 5 publications most closely related to the proposed project (italic=student)

Bierman, P. and Montgomery, D. (2013). Key Concepts in Geomorphology, W.H. Freeman, ISBN-10: 1429238607. 1st edition. 494 p.

Portenga, E. and Bierman, P. R. (2011). Understanding Earth's eroding surface with ^{10}Be. **GSA Today.**

Hunt, A.L., Larsen, J., Bierman, P.R. and Petrucci, G.A. (2008) Investigation of factors which affect the sensitivity of accelerator mass spectrometry (AMS) for cosmogenic ^{10}Be and ^{26}Al isotope analysis. **Analytical Chemistry**. 10.1021/ac701742p.

Bierman, P.R., Caffee, M.W., Davis, P.T., *Marsella*, K., Pavich, M., Colgan, P., Mickelson, D., and Larsen, J. (2003) Rates and timing of Earth surface processes from in-situ produced cosmogenic ^{10}Be, in: Beryllium: Mineralogy, Petrology, and Geochemistry, **Reviews in Mineralogy**, v. 50, Ed. E. Grew., p.147-196.

Bierman, P., Gillespie, A., Caffee, M. and Elmore, D. (1995) Estimating erosion rates and exposure ages with ^{36}Cl produced by neutron activation. **Geochimica et Cosmochimica Acta**, 59, 3779-3798.

(b) 5 most significant publications (italic=student)

Bierman, P. R., *Corbett*, L., *Graly*, J., Neumann, T, Lini, A., Crosby, B., and Rood, D., (2014), Preservation of a pre-glacial landscape under the center of the Greenland Ice Sheet, **SCIENCE**. 10.1126/science.1249047.

Bierman, P. R. and Nichols, K.K. (2004) Rock to sediment - Slope to sea with ^{10}Be - Rates of landscape change, **Annual Review of Earth Science**. v. 32. p. 215–255.

Reusser, L., Bierman, P.R., Pavich, M., Zen, E., Larsen, J., and Finkel, R. (2004) Rapid Late Pleistocene incision of Atlantic Passive-Margin River Gorges, **SCIENCE**, v. 305, 409-502.

Noren, A., Bierman, P.R., Steig, E., Lini, A., and Southon, J., (2002), Millennial scale storminess variability in the northeastern United States during the Holocene epoch, **NATURE**, v. 419, 821-824.

Bierman, P. (1994) Using in situ cosmogenic isotopes to estimate rates of landscape evolution: A review from the geomorphic perspective. **Journal of Geophysical Research** (special issue on Tectonics and Topography), 99, B-7, 13,885-13,896.

(iv) Synergistic Activities

Development and refinement of research tools – Fundamental work with graduate students developing and refining use of cosmogenic nuclides for monitoring rates of surface processes. Six major review publications (1994, 1998, 2001, 2003, 2004, 2011) and 81 refereed articles and book chapters with new cosmogenic data. Developed tools for reconstructing Holocene paleostorminess history of New England under NSF CAREER support. Donath Medal for Research by Young Scientist, Geological Society of America, 1996.

Innovations in teaching and training – NSF Directors Distinguished Teaching Scholar award, 2005. Development of student-centered, inquiry-based, data collection courses in Geomorphology, Geohydrology, and Interdisciplinary Watershed studies documented in 4 refereed papers in the Journal of Geologic Education (2010, 2003, 1999, 1996). Creation of introductory Earth Hazards class for non-science majors to increase student interest and involvement, documented in refereed lead article in EOS (2003). Lead author (with NSF CCLI support) of first new Geomorphology textbook in 20 years, *Key Concepts in Geomorphology*.

Service learning and service to community -- Urban hydrology projects with classes and interns working with Burlington city government to document loss of greenspace and increase in run off from campus neighborhoods. Documented in Nichols et al. (2003, Journal of Geologic Education). Associate Editor, Geology and GSAB; editorial board, DLESE. Chair, GSA Quaternary & Geomorphology Division (2009)

(v) Collaborators & Other Affiliations

(a) Collaborators and Co-Editors (48 months)

J Briner, Buffalo; D. Dethier, Williams College; P. Davis, Bentley College; E. Steig, UW; A. Matmon, USGS; M. Pavich, USGS;. K. Nichols, Skidmore; R. Finkel, LLNL, S. Southworth, USGS, A. Noren, U Minn; D. Rizzo, UVM

(b) Graduate and Postdoctoral Advisors

Alan Gillespie, University of Washington, graduate advisor
Rowl Twidale, University of Adelaide, postdoctoral sponsor

(c) Thesis Advisor and Postgraduate-Scholar Sponsor

A. Matmon, Postdoctoral advisor, USGS; D. McPhillips, Postdoctoral advisor, Syracuse; K. Nichols, Doctoral advisor, Skidmore College; E. Clapp, Doctoral advisor, Sevee and Mahar; L. Reusser, Doctoral advisor, University of Vermont; primary advisor, 6 PhD. and 31 MS students

Lee B Corbett, PhD Candidate
Department of Geology and School of Natural Resources, University of Vermont

(i) Professional Preparation

BA, 2003-2007, Geology, Middlebury College, Middlebury, VT
"*Multi-Proxy Climate Reconstruction on Lake Sediment from the Uinta Mountains, Utah*"

MS, 2008-2011, Geology, University of Vermont, Burlington, VT
"*Investigating the Timing of Deglaciation and the Efficiency of Subglacial Erosion in Central-Western Greenland with Cosmogenic ^{10}Be and ^{26}Al*"

PhD, 2011-2013, Earth Sciences, Dartmouth College, Hanover, NH
(Relocated to Vermont after two years)

PhD, 2013-2016, Natural Resources, University of Vermont, Burlington, VT (in progress, ABD, completion by May 2016)
"*Subglacial Landscape Evolution and Sediment Cycling in Areas of Cold-Based Ice*"

(ii) Appointments

2015	Visiting Instructor, Middlebury College Geology Department
2014-2015	Co-Instructor, University of Vermont Geology Department
2009-2014	National Science Foundation Graduate Research Fellow
2011-2013	National Science Foundation IGERT Fellow, Polar Environmental Change
2011	Visiting Instructor, Middlebury College Geology Department
2008-2009	Teaching Assistant, University of Vermont Geology Department

(iii) Products

(a) 5 publications most closely related to the proposed project

Corbett, L.B., Bierman, P.R., and Rood, D.H. *in review*. Constraining multi-stage exposure-burial scenarios for boulders preserved beneath cold-based glacial ice in Thule, northwest Greenland. **Earth and Planetary Science Letters**.

Corbett, L.B., Bierman, P.R., Lasher, G.E., and Rood, D.H. 2015. Landscape chronology and glacial history in Thule, northwest Greenland. **Quaternary Science Reviews** 109, 57-67.

Corbett, L.B., Bierman, P.R., Graly, J.A., Neumann, T.A., and Rood, D.H. 2013. Constraining landscape history and glacial erosivity using paired cosmogenic nuclides in Upernavik, Northwest Greenland. **Geological Society of America Bulletin** 125, 1539-1553.

Reusser, L.J., Corbett, L.B., and Bierman, P.R. 2012. Incorporating concept sketching into teaching undergraduate geomorphology. **Journal of Geoscience Education** 60, 3-9.

Corbett, L.B., Young, N.E., Bierman, P.R., Briner, J.P., Graly, J.A., Neumann, T.A, and Rood, D.H. 2011. Paired bedrock and boulder ^{10}Be concentrations resulting from early Holocene ice retreat near Jakobshavn Isfjord, western Greenland. **Quaternary Science Reviews** 30, 1739-1749.

(b) 5 additional publications

Bierman, P.R., Davis, P.T., Corbett, L.B., Lifton, N.A., and Finkel, R.C. *in press*. Cold-based, Laurentide ice covered New England's highest summits during the Last Glacial Maximum. **Geology**.

Corbett, L.B., Bierman, P.R., and Davis, P.T. *in review*. Glacial history and landscape evolution of southern Cumberland Peninsula, Baffin Island, Canada, constraining by cosmogenic ^{10}Be and ^{26}Al. **Geological Society of America Bulletin**.

Davis, P.T., Bierman, P.R., Corbett, L.B., and Finkel, R.C. 2015. Cosmogenic exposure age evidence for rapid Laurentide deglaciation of the Katahdin area, west-central Maine, USA, 16 to 15 ky. **Quaternary Science Reviews** 116, 95-105.

Portenga, E.W., Bierman, P.R., Duncan, C., Corbett, L.B., Kehrwald, N., and Rood, D.H. 2015. Rapid erosion rates in the Bhutanese Himalaya determined using in situ produced ^{10}Be. **Geomorphology** 233, 112-126.

Bierman, P.R., Corbett, L.B., Graly, J.A., Neumann, T.A., Lini, A., Crosby, B., and Rood, D.H. 2014. Preservation of a pre-glacial landscape under the center of the Greenland Ice Sheet. **Science** 344, 402-405.

(iv) Synergistic Activities

Development and refinement of research tools – Methodological development for extraction of *in situ* cosmogenic nuclides at University of Vermont Cosmogenic Nuclide Laboratory. Author of one conference abstract (2013) and one publication (in preparation) focused on cosmogenic laboratory methodological optimization.

Innovations in teaching – Development of new course curriculums and implementation of novel teaching tools including concept sketching and interdisciplinary field learning. Author of two conference abstracts (2011, 2012) presented in education-related sessions and co-author of one manuscript (2012) in Journal of Geoscience Education.

Laboratory training – Trainer of visiting undergraduate students, graduate students, and faculty to the University of Vermont Cosmogenic Nuclide Laboratory from 2009-present including A. Bender (Western Washington University), M. Foster (University of Colorado), A. Koester (Boston College), L. Luna (Middlebury College), D. McPhillips (Syracuse University), E. Perry (Williams College), N. Shea (University of Connecticut), and N. West (Pennsylvania State University).

Service to community – Convener of technical sessions related to cosmogenic nuclide applications at the 2013 Northeastern Geological Society of America, 2014 National Geological Society of America, and 2016 Northeastern Geological Society of America meetings.

(v) Collaborators & Other Affiliations

(a) Collaborators and Co-Authors (48 months)

B. Crosby, Idaho State University; P.T. Davis, Bentley University; R. Finkel, University of California Berkeley; J. Graly, University of Wyoming; E. Lasher, Northwestern University; N. Lifton, Purdue University; A. Lini, University of Vermont; T. Neumann, NASA Goddard Cryospheric Branch; E. Portenga, University of Glasgow; D. Rood, Imperial College London

(b) Academic Advisors

Paul Bierman, University of Vermont, graduate advisor
Jeffrey Munroe, Middlebury College, undergraduate advisor

Budget Justification - University of Vermont

Salary – We primarily request full time salary for Ms. Lee Corbett who will become laboratory manager with responsibility for training and mentoring all visitors. She will alternate with laboratory director, Bierman, conducting outreach visits and working in the field with seed grant awardees and their mentors. Her duties will include day-to-day supervision of laboratory operations for visitors, working with Bierman to evaluate seed grant requests, and working with visitors to arrange for housing and travel to Vermont. She will coordinate safety trainings and introduce visitors to all laboratory protocols. During the first three months, Corbett will work closely with Bierman to refine existing laboratory protocols for methods, training, and safety (all available at http://uvm.edu/cosmolab) into a handbook and series of trainings that will build upon those required by University Risk Management.

Bierman, as PI, requests minimal salary support, one week per summer. During the first summer, he will work closely with Corbett designing the handbook and materials for the outreach short courses. Over the next two summers and academic years, he will alternate travel with Corbett to conduct outreach both at undergraduate institutions and at schools serving populations under-represented in the geosciences. Bierman will manage the grant and interface with the evaluator.

Benefits will be assigned to Bierman and Corbett's salaries at rates negotiated by the University of Vermont. Salaries are incremented at 4% yearly per University of Vermont guidance.

Participant Support – Central to our goal of broadening participation in isotope geoscience, we have designed a seed grant program that will bring Bierman and Corbett onto minority-serving campuses and bring students and faculty from those campuses to the University of Vermont laboratory. We plan on hosting two student/faculty teams for each of three years. Below, we justify costs for participants in that program.

- Stipends – So that seed grant students can work on scientific research during the summer (when they likely have to give up summer jobs for a week or two), we will provide a $400 stipend to each student awardee.
- Travel - So that the student and faculty mentor can come to University of Vermont together to train and work in the laboratory, we will provide airfare (or mileage reimbursement).
- Subsistence – While on campus at the University of Vermont, we will provide food and housing for the seed grant awardee students and faculty mentors in University facilities during the summer. We will house awardees for a work week – the time is takes to process one batch of samples from pure quartz to BeOH jells.
- Other – To conduct their research projects, seed grant awardees must have support for laboratory work and isotopic measurements. We assume 10 samples per project, which is the size of one batch. Based on costs of prior samples, we have established *per sample* costs for the University of Vermont cosmogenic nuclide laboratory for quartz preparation and ^{10}Be extraction ($225/sample) assuming that Corbett will be doing sample preparation work with the visitors and that the quartz will be purified ahead of time by UVM graduate students associated with the laboratory. These costs include all consumables such as reagents, test tubes, and pipette tips as well as pro-rated charges for

ICP analysis and repair of laboratory equipment. AMS analyses for students will be made at PRIME Laboratory at rates appropriate for NSF-supported projects.

Travel – We request support for travel related primarily to conduct dissemination and outreach activities including:

- *Travel to professional meetings* – During year one, either Bierman or Corbett will travel to both GSA and AGU meetings in order to interact with professionals and students who might be interested in using the University of Vermont laboratory facilities. We will send emails to relevant list serves well ahead of both meetings and then schedule personal discussions over the course of the meeting with interested students and faculty. We will make announcements at venues likely to reach large numbers of geoscientists likely to be interested in cosmogenic isotopes such as AGU's Gilbert Club and QGGs annual member meeting at GSA. During year three, either Bierman or Corbett will travel will travel to GSA and present a poster or talk discussing the project and reporting the assessment data including the results of the seed grants. We request funds to cover the cost of this travel as well as meeting registration.
- *Travel to minority serving institutions for outreach short courses* – During each year, Corbett and Bierman will alternate travel to minority-serving institutions including historically black colleges and tribal colleges. We anticipate spending two days on campus including teaching the short course for one day and meeting with faculty, students and administrators on the other day. We request funds to cover the cost of this travel as well as housing and meals.
- *Travel to undergraduate institutions for outreach short courses* - Each year we will travel to three undergraduate institutions in the northeastern United States. We anticipate spending two days on each campus including teaching the short course for one day and meeting with faculty, students and administrators on the other day. We request funds to cover the cost of this travel by car as well as housing and meals.
- *Travel to assist seed grant awardees to do fieldwork and collect samples* - Each year we will travel to conduct fieldwork with two seed grant awardees. Either Bierman or Corbett will spend several days in the field with the awardees assisting both with geologic interpretations and the collection of samples. We request funds to cover the cost of this travel as well as housing and meals. We envision that seed projects will be within an easy day's drive of the awardee's home institution.

Indirect costs – Indirect costs will be charged at the negotiated on campus Public Service rate (38%) and exclude participant support costs.

Facility Support: Community sample preparation facility for broadening participation, research, and hands-on research training in cosmogenic nuclide studies

Start date, September 1, 2016

	Year 1 2016-17	Year 2 2017-18	Year 3 2018-19	Total 2016-19
SALARY				
Paul Bierman, Principle Investigator and Laboratory Director	3221	3349	3483	10053
develop training materials, outreach to schools, program evaluation				
1,1,1 weeks/summer; assume 4% annual rise				
Ashley Corbett, Senior Personnel, Academic Services Professional	45000	46800	48672	140472
full time,; assume 4% annual rise				
TOTAL SALARY	*48221*	*50149*	*52155*	*150525*
BENEFITS				
Faculty and staff: 43%, 43%, 43.2%	20735	21564	22531	64830
TOTAL BENEFITS	*20735*	*21564*	*22531*	*64830*
PARTICIPANT SUPPORT (for seed grants, 2/year)				
Stipends - for undergraduates, 1 wk @ $400, 2 per year	800	800	800	2400
subtotal	*800*	*800*	*800*	*2400*
Travel - airfare for student and advisor pairs to visit lab, $400/person, 4 per year	1600	1600	1600	4800
subtotal	*1600*	*1600*	*1600*	*4800*
Subsistence - dorm lodging and food, 5 nights, 2 people/seed grant, $70/pp*nt	1400	1400	1400	4200
subtotal	*1400*	*1400*	*1400*	*4200*
Other - Cosmogenic Nuclide Sample costs (20 samples/year)				
quartz purification and extraction at UVM, $225/sample	4500	4500	4500	13500
AMS analysis at PRIME lab, $235/sample	4700	4700	4700	4700
subtotal	*9200*	*9200*	*9200*	*18200*
TOTAL PARTICIPANT SUPPORT	*13000*	*13000*	*13000*	*29600*
TRAVEL				
Travel to Professional meetings (annouce year 1, report year 3)	2000	0	1500	3500
for Bierman or Corbett				
airfare, hotel, food, registration				
Travel to minority serving institutions for outreach short courses	3000	3000	0	6000
three trips per year, yrs 1 and 2				
airfare, hotel, food				
Travel to regional undergraduate institutions for outreach short courses	1200	1200	0	2400
three trips per year, yrs 1 and 2				
mileage, hotel, food				
Travel to field to assist seed grant awardees collect samples	2000	2000	2000	6000
two trips per year, all years				
mileage, hotel, food				
TOTAL TRAVEL	*8200*	*6200*	*3500*	*17900*
TOTAL DIRECT COSTS	77155	77914	78186	233255
TOTAL INDIRECT COSTS (Public service, on campus rate, 38%)	29319	29607	29711	88637
TOTAL PARTICIPANT SUPPORT	13000	13000	13000	29600
TOTAL COSTS	119474	120521	120897	351492

UVM Cosmogenic Nuclide Sample Preparation Facilities

The University of Vermont is particularly well equipped to conduct the proposed research with a new and already heavily used cosmogenic isotope preparation laboratory. In the past 6 years, we have processed over 3500 samples with chemical extraction done by 10 UVM graduate students, a post-doctoral associate, and 9 undergraduate and graduate students visiting the lab for several week to several month residencies from University of Connecticut, Penn State University, Duke, Macquarie University, Williams College, Federal University of Brazil, Western Washington University, and Skidmore College. After an electrical fire in May 2007, the cosmogenic nuclide extraction laboratory was completely rebuilt. An extensive web page documents the lab, the projects in which we are involved, and provides copies of all the laboratory methods at:

http://uvm.edu/cosmolab

The new clean room laboratory is state of the art with its own computer-controlled air handling system that provides ULPA-filtered air to the working spaces. There are separate lab rooms and teflon ware for processing meteoric and *in situ* ^{10}Be. We have a total of five fully exhausting laminar flow fume hoods made by TFI. All hoods are equipped with wash down systems for Perchloric Acid providing maximum flexibility and allowing the laboratory to support multiple sample processing activities at once. We maintain separate hoods and lab ware for high- and low-level *in situ* samples. Lab design and construction minimized the use of boron-bearing materials in both the rooms and the air-handling system. As a result, boron levels in targets prepared in the lab are very low, allowing accurate and precise measurements of ^{10}Be at exceptionally low levels. Carrier process blanks consistently have $^{10}Be/^{9}Be$ ratios well below 10^{-15}.

Over the past several years, we have refined our sample processing methods to make them more robust (Hunt et al., 2006, 2007, 2008), reduce boron, and increase beam currents to improve precision. Over the last year, beam currents at LLNL average 24+/-2 uA, allowing rapid and precise AMS analysis of all sample types and exceptionally low detection limits. During the recommissioning of the lab, we documented our methods extensively so that we can rapidly train new users and so that the results are more consistent; methods are available from the laboratory web site. In addition, we have instituted ICP-based yield and purity checking procedures for every batch of samples. These procedures determine sample quality by taking small aliquots during various steps of the extraction process. Having our NSF-supported JY Optima 2C in the adjacent lab makes for same day turnaround and allows us to continually monitor the efficiency of the extraction process.

In addition to the dedicated clean laboratory, we have a separate dedicated laboratory for preparation of quartz mineral separates. With 10 ultrasounds, we are capable of rapidly extracting sufficient quantities of pure quartz for analysis (typically 20-40 grams) at a rapid pace. We share up-to-date rock crushing facilities with the rest of the Geology Department. These facilities include a jaw crusher, plate grinder, sieve shaker, and a high volume, roll-type magnetic separator.

Quartz purification laboratory with dedicated polypropylene hood for acid transfer and 10 ultrasonicators for sample treatment.

Hunt, A.L., Larsen, J., Bierman, P.R. and Petrucci, G.A. (2008) Investigation of factors which affect the sensitivity of accelerator mass spectrometry (AMS) for cosmogenic ^{10}Be and ^{26}Al isotope analysis. **Analytical Chemistry**. 10.1021/ac701742p.

Hunt, A.L., Petrucci, G.A., Bierman, P.R. and Finkel, R.C. (2007) Investigation of Metal Matrix Systems for Cosmogenic ^{26}Al Analysis by Accelerator Mass Spectrometry **Nuclear Instruments and Methods in Physics Research** Section B: Beam Interactions with Materials and Atoms, B260, p.633–636.

Hunt, A.L., Petrucci, G.A., Bierman, P.R. and Finkel, R.C. (2006) Metal matrices to optimize anion beam currents for accelerator mass spectrometry: **Nuclear Instruments and Methods in Physics Research** Section B: Beam Interactions with Materials and Atoms, v. 243, n. 1, p. 216-222, doi:10.1016/j.nimb.2005.07.220